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MARGINAL GLACIAL DRAINAGE FEATURES IN THE FINGER LAKE REGION[1]

JOHN L. RICH
Cornell University, Ithaca, N. Y.

A study of a considerable number of the channels or scourways formed by streams associated with the Pleistocene ice sheet in the southern Finger Lake region of New York has served to bring out many features of more than local interest and importance, both as to the broader phases of glaciation in this part of New York State, and as to the value of a study of such channels as an aid in working out the glacial geology of a region.

This study has a distinct bearing on the interglacial problem in that several of these channels give conclusive evidence of more than one stage of glaciation, while one points strongly to three or more such stages with corresponding interglacial epochs, some of which seem to have been considerably longer than post-glacial time. Other channels are so situated as to make possible a fairly accurate estimate of the slope of the ice margin along the valley tongues. Still another furnishes proof of an extensive sinking of the surface consequent upon the melting-out of a large block of buried ice—a phenomenon, the importance of which seems not to be fully appreciated.

The Finger Lake region, lying as it does along the belt of the great recessional moraines of the Wisconsin ice sheet, is especially favorable for the study of marginal glacial drainage features. The long halts of the glacier, while the moraines were building, gave ample time for the associated streams to carve for themselves distinct channels which, now that the ice is gone, are in most cases left dry and entirely out of harmony with the present drainage.

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[1] This paper is an abstract of a thesis presented to the faculty of Cornell University in June, 1907, as a requirement for a major in Physiography. The work was undertaken at the suggestion of Professor R. S. Tarr, to whom the writer is indebted for helpful suggestions, and for the location of many of the channels herein described. In the course of folio work for the U. S. Geological Survey, Professor Tarr discovered several of these channels, some of which are described in his report soon to be published by the Geological Survey.

CHANNEL TYPES

The glacial channels of the Finger Lake region are of several different types, representing various conditions of formation, ranging from small streams at the ice margin to the outlet streams of large glacial lakes. It has been found desirable in describing these channels to classify them into five groups, based on the most common conditions of formation. The following five types have been selected:

I. *Marginal.*—Channels formed by streams flowing close along the ice margin.

II. *Submarginal.*—Channels of a broadly marginal nature; not, however, following closely the edge of the ice; cutting across hill spurs or behind small outlying hills.

III. *Lateral.*—Channels formed by streams leaving the glacier through a notch in the bordering hills and flowing laterally away from the ice.

IV. *Morainic channels.*—Channels formed while a moraine is building by contemporaneous streams issuing from the ice. Often indistinct; best developed in flat moraine near the end of an ice-lobe.

V. *Glacial lake outlets.*—Channels formed by the outlet streams of glacier-dammed lakes.

It must be borne in mind that it is often difficult, if not impossible, to draw sharp lines of distinction in all cases. This is necessarily so because of the variations in conditions under which the channels were formed.

In this paper only selected examples of each type are described. In so far as possible channels have been selected which illustrate well the type, and at the same time show features of more than local interest.

TYPE I. MARGINAL

Slaterville channels.—One of the most typical channels of the marginal type is found about two miles east-northeast of Slaterville Springs (Dryden sheet, U.S.G.S.) on the east side of Six Mile Creek valley at an elevation of about 1,640 feet near the top of the southmost hill. The channel starts as a slight trimming of the hill slope. This increases gradually until at first a flat bench, and later a two-sided channel is cut in the slope (Fig. 1). The channel bottom has a width of about one hundred feet and is very flat and swampy. A profusion of trunks and branches of hemlock trees is scattered over the bottom; a rather characteristic feature of such channels in this region. The lower bank, or the one which was nearest the ice, is low, varying from two to ten feet in height. The opposite bank, formed by trimming of the hillside, is very steep, and thirty or forty feet high in places. The channel, beginning on the west side of the hill, follows closely the contours around the south end to the east side, where it becomes lost for a short distance as it crosses a small valley or gully, but reappears again, though less distinctly, beyond.

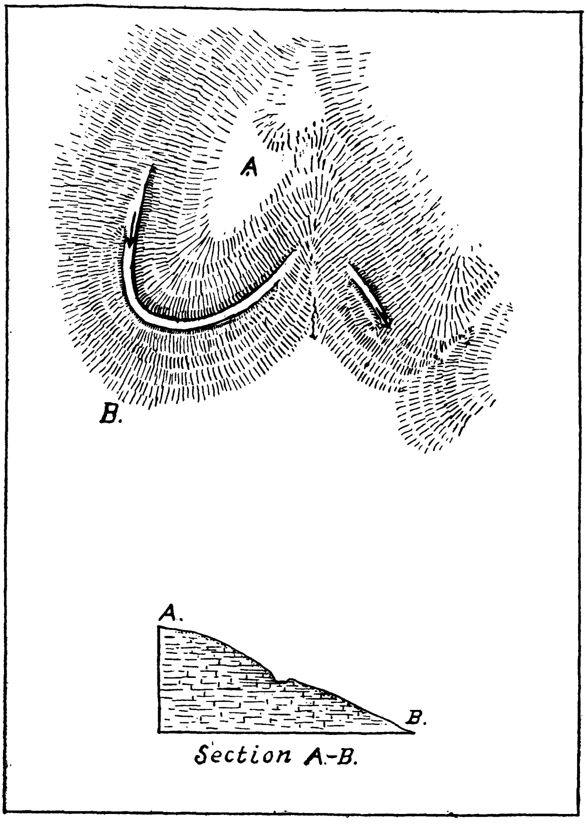

FIG. 1.—Sketch of Slaterville Springs channel, showing its contour-like character.

An interesting feature is the disappearance of the channel in crossing the small valley, and its re-appearance on the opposite side. It may be that a block of stagnant ice, probably more or less buried, lay in the valley and formed the stream bottom. If such were the case we would expect to find no distinct channel after the ice had melted.

At an elevation two hundred feet lower on the same hill, and almost due southwest of the channel just described is another of the same general type. It begins on the west slope of the hill as a shallow, indistinct, slightly swampy channel with banks varying in height from one to three feet. After continuing thus for about 150 feet it suddenly changes, at the site of an ancient waterfall, to a deep partly rock-sided gorge which contours the hill for a distance of about one-fourth mile. Its depth here is approximately forty feet. A short distance east of the mouth of this channel is another shorter one cut in the rock at the base of the hill. The two were probably contemporaneously formed by the same stream.

Several features of this channel show that it was formed previous to, or during the *advance* of the last ice-sheet, and that streams associated with the *retreating* Wisconsin ice did little more than to clear out a part of the débris with which the channel had been filled. The lines of evidence pointing to this are: (1) the present V-shape of the gorge, (2) the presence of considerable drift within the gorge, and (3) the only occasional outcrop of rock in the gorge walls. The bottom is not flat as would be expected if the gorge had been cut by the last stream which flowed through it. The flat portion of the bottom is very narrow; only a fraction of the width of the gorge, and in no part of the bottom is rock visible.

This is one of two channels among the large number studied, in which the sites of waterfalls were found.

Wedgwood channel.—One and one-half miles west-southwest of Wedgwood Station (No. 1, Fig. 2, from Watkins sheet, U. S. G. S.) is a marginal channel distinctly older than the final retreat of the last ice-sheet. It is now largely drift-filled and shows no trace of the presence of a stream since it was uncovered by the ice. It is not flat bottomed, as are the undisturbed channels, but has a decided V-shape. East of the channel a small rock hill has been isolated by the channel cutting. Rock is exposed in the walls in only a few places. One exposure at *X* (Fig. 3) shows an approximately vertical rock wall buried beneath the glacial drift which partially fills the gorge. A few feet north of *X* the channel bottom rises several feet to a drift divide which is distinctly *within* the main channel, but shows no trace of stream action. Beyond the divide a hummocky deposit continues nearly to the small stream which here crosses nearly at right angles to the direction of the channel. In this stream, approximately in line with the west channel wall, is a waterfall probably formed by the

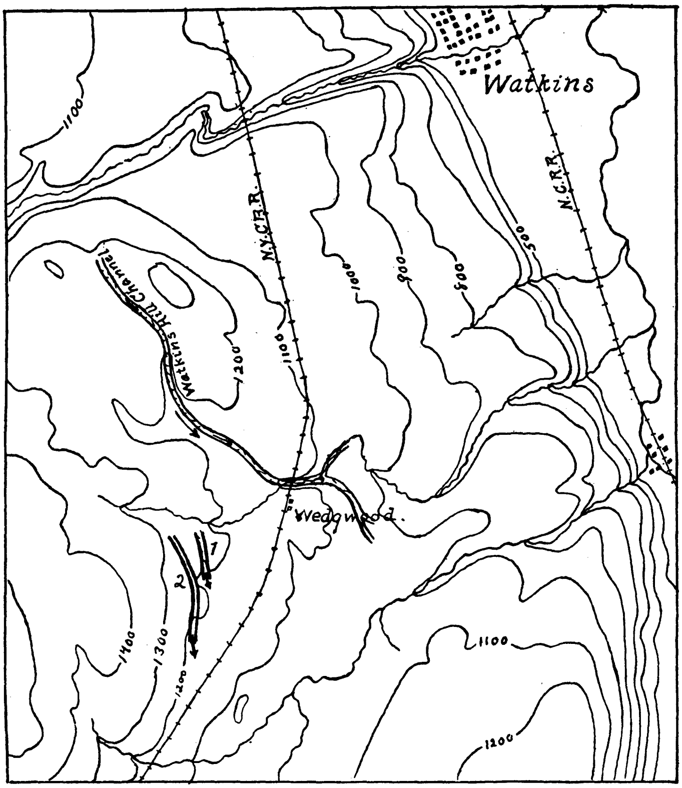

FIG. 2.—Wedgwood and Watkins Hill channels. These channels were formed at the margin of an ice-lobe moving southward through the Seneca Lake valley shown on the eastern side of the map. Scale 1/62,500.

present stream encountering the rock wall of the buried gorge. A short distance below the fall the conditions shown in *A–B* (Fig. 3) may be seen. There is a rock terrace about thirty feet wide at a level three feet above the present stream. The stream, however, is not flowing on rock. It seems to have discovered a buried channel, for both its bottom and its southwestern side are composed of drift.

This condition of the stream, together with the occurrence of the falls a short distance above and the rocks walls at *X*, indicates the presence of a buried gorge extending at least as far north as the stream, beyond which, if present, it is entirely concealed by drift.

Only a few hundred feet west of the channel just described, and a little further up on the hillside (2, Fig. 2) is another of a strictly marginal type which follows for over one-half mile along the hill. There is here distinctly a channel within a channel; the smaller and later one formed during the final retreat of the ice; the other at an earlier date. The older channel is partially drift-filled, yet maintains distinct banks throughout most of its course. The banks are not

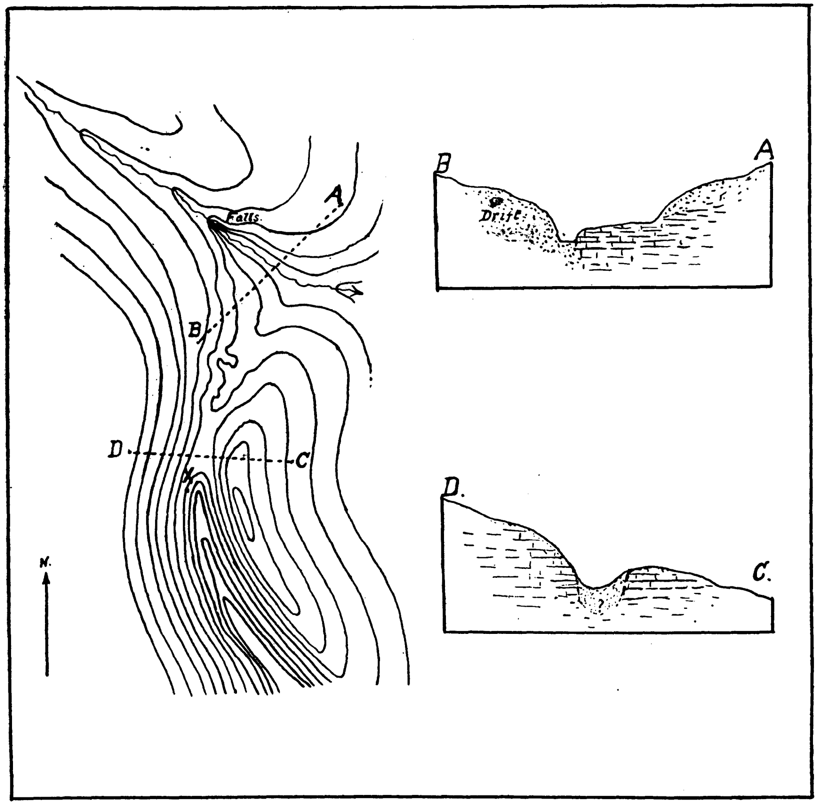

Fig. 3.—Sketch of Wedgwood channel (1). Scale of contour sketch about six hundred feet to the inch. The profiles are slightly exaggerated to bring out essential features.

sharply trimmed. In the lower end are several hummocks, apparently of a morainic nature. This older channel was occupied during the retreat of the last ice-sheet by a small stream which formed a second channel twenty or thirty feet wide within the older one, which has a width of about 125 feet. The smaller channel has distinctly trimmed though low banks, and a characteristically swampy bottom. At its upper end the older channel is buried in a gently undulating moraine in which the smaller and later stream seems to have originated.

TYPE II. SUBMARGINAL

Cayuta Gorge channel.—An excellent example of this type is Cayuta Gorge at the outlet of Cayuta Lake (Fig. 4; Ithaca sheet, U. S. G. S.). The lake lies in a broad, mature valley trending a little south of southwest. At its southern end a glacial deposit, about forty feet in average height stretching across the valley, forms the dam to which the lake owes its origin. In one place on the west side of the valley near the schoolhouse the top of this barrier is less than twenty feet, and probably not more than ten feet above lake level. Through this gap to the south is free communication with Catlin Mill Creek, and thence with Seneca valley; yet the lake waters, instead of finding an outlet through this low pass, turn eastward and escape through a rock gorge cut to a depth of over three hundred feet through the hill bordering Cayuta valley on the east (Fig. 4). That this outlet is no normal valley, is shown by its almost perpendicular rock sides and its lack of harmony with the surrounding topography. Clearly nothing but the intervention of a glacier could have produced such an abnormal drainage condition in a region of horizontal and comparatively homogeneous rocks.

As is show by a map of the moraines of this region,[1] a lobe of ice from the great Seneca valley-tongue lay for a long time across the lower end of Cayuta Lake valley. Such an ice-lobe would obstruct the normal drainage and cause the water to escape over the lowest point in the valley side. This, in this case, clearly must have been the site of the present gorge. In order to permit the cutting of so profound a gorge, the glacier must have stood nearly stationary for a long time. It might have been melting away as fast as the gorge was being cut down, but no faster, for if melting were more rapid than downcutting, a new channel farther down the hillside would at once be begun.

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[1] Tarr, *Bul. Geol. Soc. Am.*, Vol. XVI, 1905, pp. 215–28.

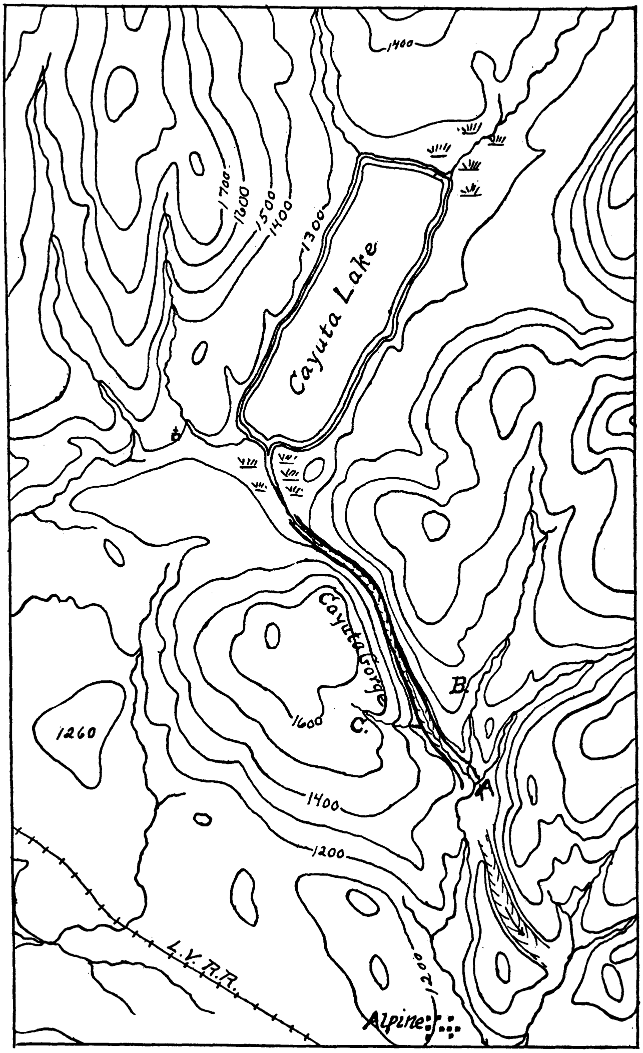

FIG. 4.—Cayuta Gorge and vicinity. Note tributary streams *A*, *B*, and *C*, referred to in the text. Scale 1/62,500.

A channel of this type could be formed only in connection with a *retreating* or possibly stationary phase of ice-movement; never in connection with an advancing movement, for, since the initial stage of such a channel begins high up on the hill, if after the channel had been started the ice continued to advance, the channel would soon be covered and another farther up the hill slope would be begun. Such reasoning strongly supports the belief that this channel was formed by waters associated with a retreating ice-sheet. It was not, however, formed during the final retreat of the last ice, for within the gorge itself are deposits of glacial drift which the stream is still engaged in removing. It has nowhere as yet reached rock bottom. The presence of the drift clearly proves that, after the gorge had been cut to a depth greater than the present, it was subjected to glacial action.

The cutting of the gorge has introduced a hanging condition in the streams *A*, *B*, and *C* (Fig. 4). The stream *C*, which, as the map shows, has only a small drainage area, enters Cayuta Gorge without falls through a drift-filled rock gorge thirty or forty feet in width. The stream bottom, at least in the lower part of the gorge, is entirely on drift. The presence of this drift-filled tributary gorge shows that, since the glacial epoch during which Cayuta Gorge was formed, there came an erosion interval long enough for a small stream to cut a good-sized rock gorge. After this period of erosion came another epoch of glaciation during which the gorges were filled with drift. Since glacial times this stream, working over a very steep grade, has been unable to remove the drift from the gorge which in the interglacial interval it had cut in solid rock. This would indicate that the ratio of interglacial to postglacial time is roughly that of the time taken by a stream to cut a gorge in rock to that taken by the same stream to cut a gorge of about equal size in drift.

Stream *B* shows an even more complex history. It enters Cayuta Gorge at a rather steep grade through a gorge which is distinctly interglacial in character. Its walls are veneered with drift and appear much weathered. The stream, which flows in a series of cascades over a rock bottom seems to have deepened its channel in the rock by about six feet since glacial times. One-fifth of a mile above its mouth the gorge widens out into a nearly circular amphitheater (Fig. 5) at which there is an abrupt change in direction and an absolute change in the character of the gorge. For one-half mile or more above the amphitheater the stream flows with an even grade through a rock-walled, partly drift-filled gorge at least three times wider than that below. The gorge bottom in this upper part is about 120 feet wide and shows rock in only one or two places, then not sufficiently to cause falls or rapids. The walls show marked decay. In line with this upper gorge and running from the amphitheater to the side of Cayuta Gorge is a sag of about fifteen feet in the surface which undoubtedly marks the drift-filled continuation of the gorge above (see Fig. 5).

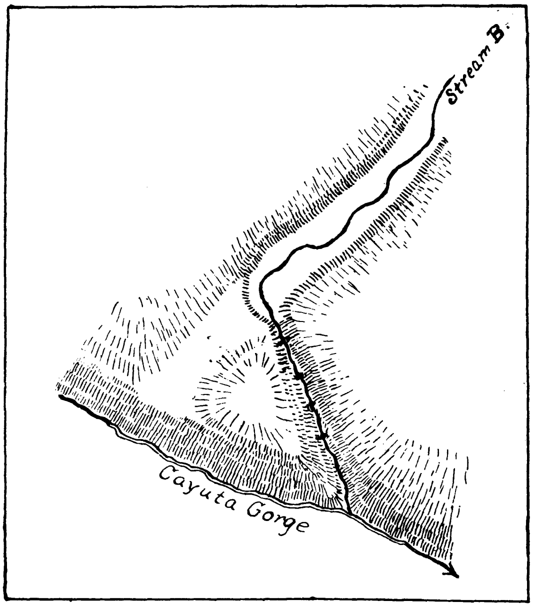

FIG. 5.—Sketch of tributary Stream B. Note the broad upper gorge, and the narrower one, itself interglacial, through which the stream reaches Cayuta Gorge.

The Stream *B*, then, above the amphitheater, is flowing in a gorge distinctly broader and older than the interglacial one which it follows from the amphitheater to its junction with Cayuta Gorge. If this larger gorge is due to a hanging condition initiated by the cutting of Cayuta Gorge then, in order to explain the facts, appeal must be made to three periods of glaciation; for what but the intervention of a glacier would account for the diversion of the stream from its broader gorge to the one, itself interglacial, which it occupies in the lower part of its course? It has been suggested however, that the older gorge may be the result of a regional rejuvenation antedating the appearance of the first ice-sheet. Such a rejuvenation, evidence of which has been found by Tarr in many of the streams of this region, might account for the conditions here found without appeal to more than two periods of glaciation.

It seems probable, however, if Stream *B* cut a gorge due to regional rejuvenation that it was tributary to the neighboring Stream *A* rather than to Cayuta Gorge. This belief is based on the fact that the drift-filled gorge at the mouth of *B* appears to be hanging well above the present stream in Cayuta Gorge, and that in *A*, about one-third of a mile above its mouth, there is a break in the continuity of the rock wall on the west side, above which the gorge is decidedly narrower; a condition which suggests strongly the entrance of a large tributary gorge from the west.

For these reasons, though one gorge may be due to rejuvenation, it is believed that the others represent at least three ice invasions with corresponding intervals of deglaciation.

Evidence as to the interglacial nature of these gorges is of considerable importance, owing to the fact that while the multiplicity of glacial epochs has been proven in many parts of the United States, it has not been fully recognized for this region. As late as 1905 we have the following statement from Fairchild[1]: "It is safe to discuss the history of the region as involving only the Wisconsin glacial epoch, for no evidences of any earlier and more forceful and extended ice sheet have been found." Previous to 1906, Tarr[2] held that there was no direct evidence of more than the Wisconsin ice invasion. In that year, however, he published evidence based on the buried gorges which led him to the conclusion that there have been at least two epochs of glaciation.[3] Maston[4] in 1904 described a series of buried gorges in Buttermilk valley near Ithaca which led him to the belief that at least two and perhaps four ice-sheets had invaded this region.

TYPE III. LATERAL

Spencer Summit channel.—A typical lateral channel is found one and one-half miles east of the Lehigh Valley railway station at Spencer Summit, a short distance south of the Thompkins County line and one-fourth mile east of Michigan Creek (Dryden sheet, U.S.G.S., Fig. 6). Beginning just beyond the divide in the deep notch through which the road passes, it follows a southeasterly course along the preglacial valley heading near the notch. For the first mile of its course the channel is very distinct, flat bottomed and from 100 to 150 feet in width. Farther down it is less distinct owing to the entrance of tributary valleys whose streams have modified the old channel bottom.

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[1] *Bul. Geol. Soc. Amer.*, Vol. XVI, p. 67.

[2] *Ibid.*, pp. 217, 237–42.

[3] *Jour. Geol.*, Vol. XIV, 1906, pp. 18–21.

[4] *Ibid.*, pp. 133–51

Contrary to what would be expected, the channel does not begin at the divide. Here the notch is V-shaped in cross-section, and at the bottom scarcely wider than the highway. Rock is visible in the walls, but there is a considerable drift filling. About two hundred feet east of the divide the channel begins suddenly. It is very swampy and attains almost its full width at the very beginning.

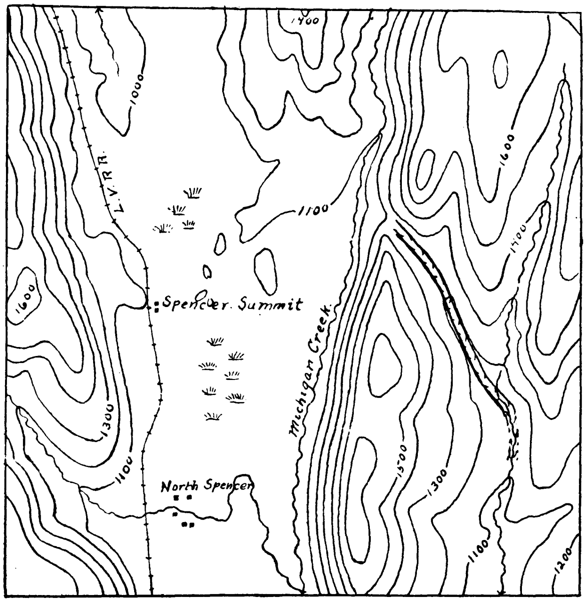

FIG. 6.—Spencer Summit channel. A typical lateral channel. The ice-tongue moved southward through the deep, steep-walled valley in which Spencer Summit is situated. Scale 1/62,500.

A probable explanation of the absence of the channel at the divide is that a small ice-lobe from the main Cayuga valley tongue pushed partly through the notch, and from its terminus discharged the stream which formed the channel. This is a condition almost exactly similar to that found by Tarr at Floral Pass, along the eastern border of Hayden Glacier, Alaska.

Johnson Hollow channel.—Two and one-half miles north of the town of Millport, and an equal distance east-southeast of Moreland is the beginning of another interesting lateral channel. It was formed by a stream from a small lateral lobe which pushed from the great Seneca valley ice-tongue for a short distance through the gap in the hills on the west side of the valley. The stream flowed for a little over a mile in a northeasterly direction, almost opposite to that of the ice-motion in the adjacent valley. It then turned and flowed a little south of west for another mile, then southward through Johnson Hollow and finally back to the ice three miles below the starting point. (See Fig. 9.)

This channel, like those already described, has a flat, swampy bottom and distinctly trimmed banks. For the first mile of its course its width varies from 100 to 150 feet. The elevation at the beginning is 1,200 feet, and at the foot of Johnson Hollow, where it again reached the ice tongue, 1,000 feet. This gives a drop of two hundred feet in a distance of three miles, or an ice-slope of sixty-six feet per mile.

At the head of Johnson Hollow is a series of several channels of which this is one. The entire series will be fully described on a later page with special reference to the relation of the various channels to each other and to the ice-front.

Watkins Hill channel.—Beginning on the west side of Watkins Hill (Fig. 2, Watkins Sheet, U. S. G. S.) is another lateral channel which after a course of about two and one-fourth miles, again reached the ice-tongue, against which it built a distinct gravel plain. The difference in elevation of the two ends of this channel is approximately 150 feet. This, in two and one-fourth miles, gives an ice slope of sixty-seven feet per mile; practically the same as that determined for the Johnson Hollow channel.

Remarks.—The condition favorable for the formation of a lateral channel is the presence of an ice-tongue lying in a valley bordered by hills. Under these conditions the marginal drainage is apt to be diverted by any low gap in the valley sides, giving rise to a lateral channel. It often happens that a stream after thus leaving the ice finds itself in a valley tributary to that in which the ice-tongue lies. It will then, after a longer or shorter course, return to the main valley. If it finds this still occupied by the ice, a marginal deposit, either a gravel plain or a delta, will be formed. Which of the latter is formed will depend on whether or not a marginal lake is held up in the tributary valley. When such a deposit is preserved the two points, one where the stream leaves the ice, and the other where it again reaches it, furnish valuable data as to the position and slope of the glacier tongue at the time the deposits were forming.

TYPE IV. MORAINIC CHANNELS

None of the morainic channels studied show features worthy of separate description. A short summary of the most characteristic features of such channels is therefore given instead of detailed descriptions of individual channels.

Morainic channels as seen in the region of the Finger Lakes are characteristically weakly developed. They are often short, irregular, and marked in many cases by scarcely more than a modification of the drift into flat, stream-bottom form. Such a condition is what should be expected. The ice while a moraine is building is subject to more or less backward and forward oscillation. Temporary streams are developed here and there, and under most conditions the great amount of morainic débris supplied to these streams causes them to aggrade rather than to degrade; to build up the channel bottom rather than to cut it deeper. Hence the prevalence of broad, flat-bottomed channels with ill-defined banks.

TYPE V. GLACIAL LAKE OUTLETS

Watkins Lake outlet.[1]—The outlet of Lake Watkins, held up by the glacier in Seneca valley, has already been described in part by Fairchild[2] and later by Watson.[3] Both, however, failed to see and describe the most interesting part of the channel—its beginning and the first one and one-half miles of its course. Both described the channel as beginning at Pine Valley (Fig. 7; Elmira sheet, U. S. G. S.) and continuing southward past Horseheads to the Chemung River at Elmira. Pine Valley was considered the site of the lake outlet as is shown by the following from Watson:[4] "This channel has an equally

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[1] In connection with his folio work, Tarr first discovered the part of this channel above Pine Valley.

[2] *Bul. Geol. Soc. Am.*, Vol. VI, 1894–95, pp. 365–68.

[3] *N. Y. State Museum Rept.*, Vol. LI, 1897, p. 74.

[4] *Loc. cit.*, p. 74.

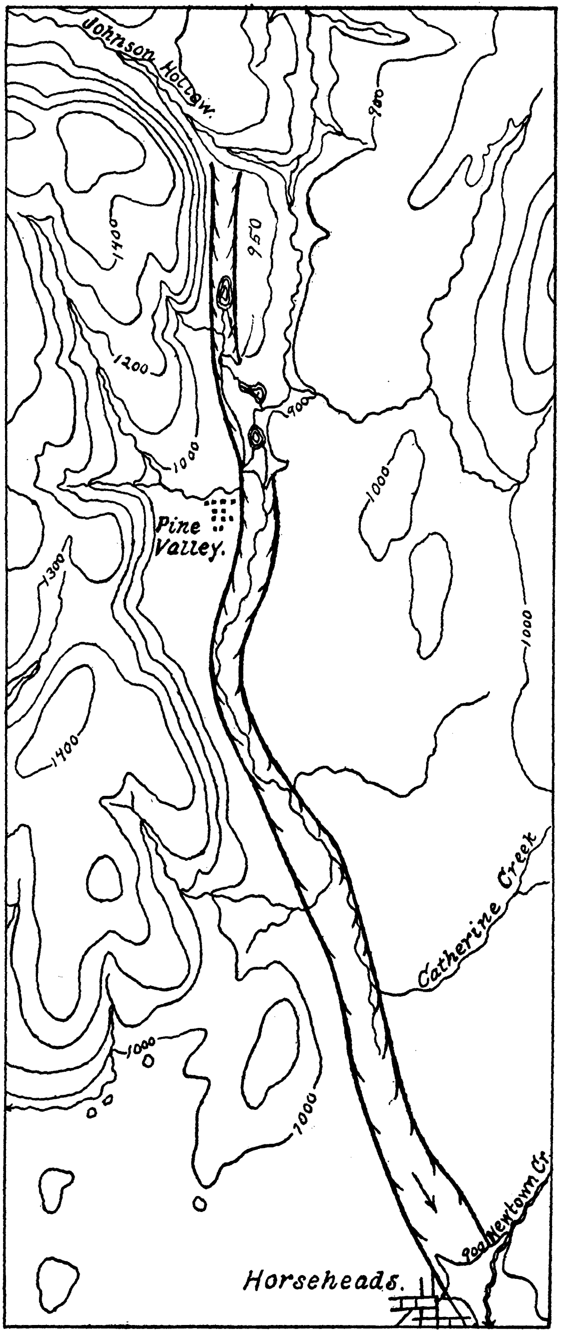

FIG. 7.—Map of Watkins Lake outlet. As a result of the melting-out of buried ice after the outlet waters had ceased flowing, one side and a part of the bottom of the channel just north of Pine Valley has dropped out. Scale 1/62,500.

slight gradient northward as far as Pine Valley where the glacial lake properly began, as to the south into Elmira."

The failure of these authors to recognize the true beginning of the channel is probably due to the peculiar drainage condition now prevalent in the channel. Two miles north of Horseheads, Catherine Creek enters the old channel and, turning northward, follows it with very slight gradient as far as Pine Valley, where, one-half mile north of the village, its grade suddenly becomes steeper as it leaves the channel and flows the remainder of the distance to Seneca Lake delta through a deep drift valley (Fig. 7).

The question at once suggests itself: Why does Catherine Creek flow northward in the channel in a direction opposite to that taken by the glacial waters? Tilting of the land may be suggested as an explanation, for it is well known from the studies of Gilbert that this part of New York has suffered deformation since glacial times. Tilting, however, does not offer a solution of the problem, for the land was tilted toward the south, with uplift in the north. This would increase the grade of the channel rather than decrease it sufficiently to cause a reversal of drainage. A more satisfactory explanation may be found in the fact that Newtown Creek, which enters the channel at Horseheads, has built a fan across it, and by ponding back the normal stream in the channel has caused the reversal of drainage. Were it not for this fan, if a lake were now held up in Seneca valley, it would outflow at Pine Valley. Nevertheless, in glacial times the outlet was not here but was one and one-half miles north of the village close to the base of the steep hill at the mouth of Johnson Hollow.

The channel at the beginning has a width of 700 feet; gravelly bottom and distinct, clear cut, and approximately straight banks from fifteen to forty feet in height. At the first road crossing, one mile below the beginning, a small stream entering from the hills on the west has built a very perfect alluvial fan entirely across the channel and caused the formation of the shallow pond shown in Fig. 8. Below this the channel continues for about one-half mile to near the road leading into Pine Valley. For the next half-mile southward through the village one side of the channel and a part of the bottom have literally dropped out. Near the road the west bank and the west half of the channel are intact; the east half of the bottom and the east bank have dropped down, leaving a depression now occupied in part by a pond at a level three or four feet below that of the channel bottom. Into this depression and its continuation northward Catherine Creek now flows. It is here that Watson and Fairchild evidently placed the outlet of Lake Watkins.

Obviously there has occurred here a settling-down of a portion of the drift in the central part of the valley since glacial times; certainly since the waters of glacial lake Watkins ceased flowing through the channel, for had the settling occurred while the stream was still flowing, the depression thus formed would immediately have been filled with gravel. Besides, had the depression existed then as now the lake would have overflowed at this point rather than at a higher level farther north.

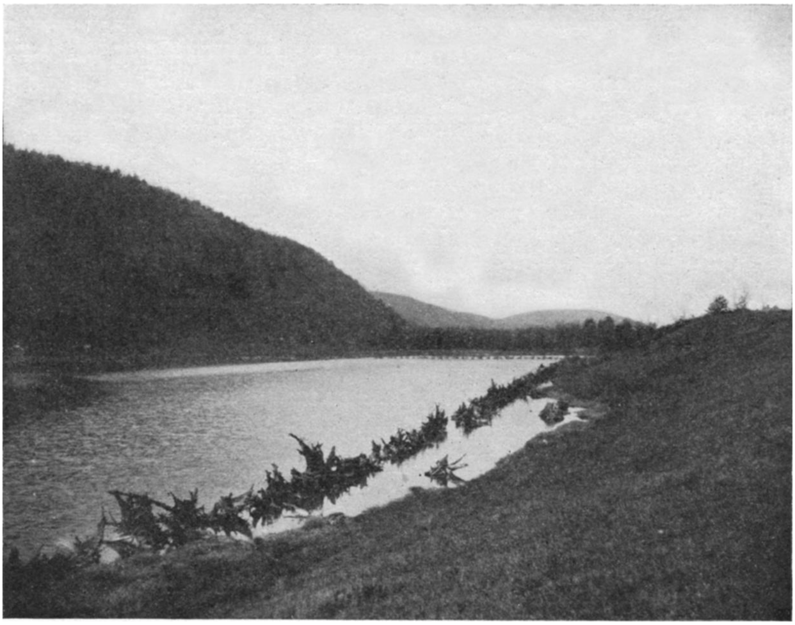

FIG. 8.—Watkins Lake outlet. Looking up-stream from a point one mile below the beginning. The shallow pond in the foreground is caused by the blocking of the channel by an alluvial fan.

The melting of an ice mass buried beneath glacial gravels is suggested as the cause of the settling.[1] Ice thus buried would melt away very slowly. In this case it must have remained at least until the glacier had withdrawn far enough to permit the waters of Lake Watkins to find an outlet at a lower level.

The conditions at Pine Valley and northward to Seneca Lake are especially favorable for the burial of an ice block. In this part of Seneca valley, which is comparatively narrow and gorge-like, there lay a long tongue of ice. The valley is now drift-filled to an unknown, but certainly great, depth, at least several hundred feet as is indicated by borings at Watkins and Pine Valley. Presumably at the time of maximum glaciation the ice completely filled the valley down to the rock at the bottom. As the glacier retreated, melting would take place largely at the surface, or at least more rapidly at the surface; with the result that at the surface retreat would be more rapid than deep in the valley bottom. Since the glacial waters escaped to the south at a level certainly considerably higher than that of the bottom of the ice, outwash gravels from the more rapidly melting upper part would spread over and bury the lower ice. Ice thus buried would melt away slowly and in melting allow the settling of the overlying drift; producing conditions like those actually found at Pine Valley.

The topography strongly indicates that the axis of Seneca valley for several miles north of Pine Valley was occupied by an ice-block which in melting allowed the slumping of the overlying drift.

THE JOHNSON HOLLOW CHANNELS

At the head of Johnson Hollow (Watkins sheet), is an important series of connected channels illustrating four of the types described in the preceding pages, and showing their relations to each other and to the ice front. (See map, Fig. 9.)

At the time the channels were forming, a lobe of ice from the main Seneca valley tongue pushed into the Moreland valley; ending near the head of Johnson Hollow. At the same time the ice in the Seneca valley extended several miles farther south. The drainage from the margin and end of the Moreland lobe, together with a lateral stream (*E*) from the Seneca valley tongue, united at the head of Johnson

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[1] The agency of a buried ice mass had been suggested by Tarr as an explanation of this particular condition, even before the direct evidence of the sinking of the channel bottom had been found.

Hollow and flowed as a single large stream, southward and southeastward to the foot of the hollow where it emptied into a marginal lake held up by the ice of the Seneca valley tongue.

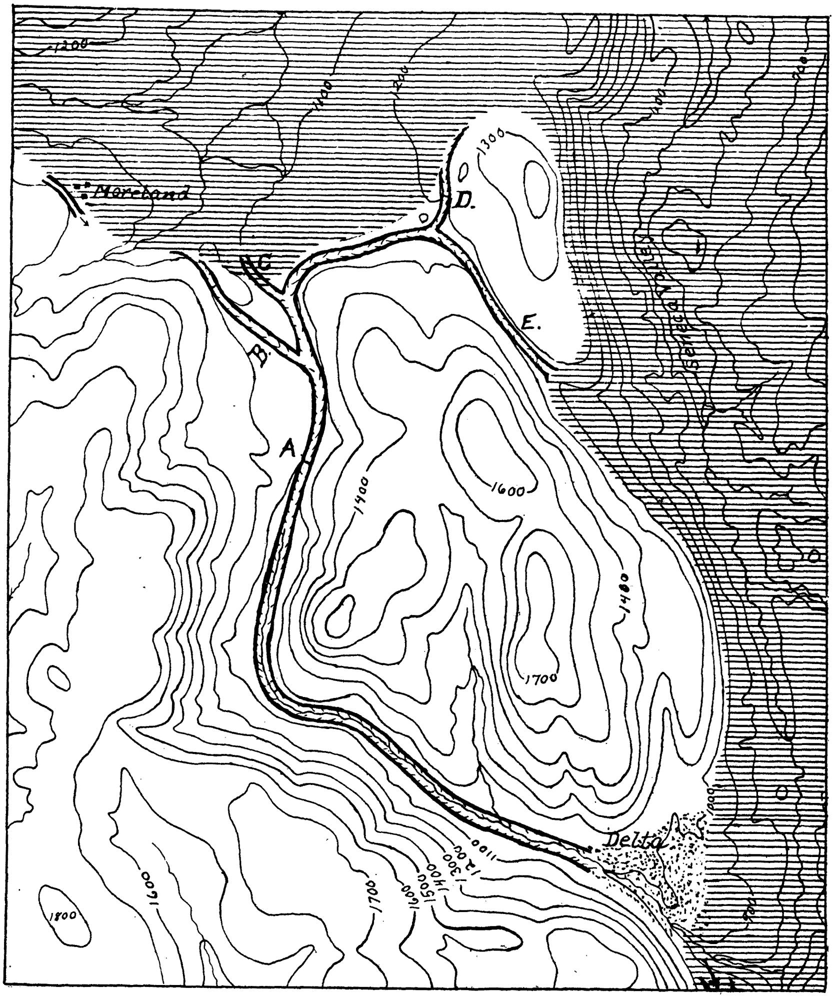

FIG. 9.—Johnson Hollow Channels. The probable position of the ice at the time the channels and delta were forming is shown by the ruled area. The Watkins Lake outlet begins at the base of the hill near the southeast corner of the map. Scale 1/62,-500.

Four of the channel types, *marginal*, *lateral*, *morainic*, and *lake outlets*, are represented in this series. Channel *B*, at the beginning, is strictly marginal. Farther down it swings behind a low knoll probably of rock; then takes a straight course southeastward to the main channel. *C*, which was probably initiated by a stream flowing from the end of the ice-lobe, seems later to have developed into a lake outlet, draining a lake held up in the Moreland valley by the retreating Moreland lobe. Channel *D*, formed along the eastern margin of the Moreland lobe, may be classed as marginal-morainic. It enters the main channel *E* as a rather deep trench with banks only moderately trimmed. Its lower portion might well be mistaken for a small valley cut by a post-glacial stream were it not for the fact that the only stream, a very small one, which enters it has built a fan across it. In its upper part the channel becomes shallower and finally one bank, the western, disappears. The other continues for considerable distance farther, gradually becoming less and less distinct.

E has already been described (p. 539). The main channel below A, is very pronounced, flat bottomed, and from four hundred to six hundred feet in width, with sharply trimmed drift banks twenty to thirty feet high.

An interesting drainage condition is found in connection with these channels. One-half mile below the junction of *A* and *B* a stream from the hills on the east has built a fan entirely across the channel. This has completely reversed the drainage of the channels above the fan, causing all the water to flow out northward through *C*, and thence to the stream in the Moreland valley. The grade of *C*, which was doubtless a lake outlet, is so low that a slight blocking of the channel three-fourths of a mile below was sufficient to reverse its stream.

In so far as could be determined, these channels were practically contemporaneous in origin, except that *C* must have persisted longer than the others. There is no apparent hanging condition at the junction of any of the channels with the main one as might be expected if the stream in one ceased flowing for any considerable time before that in the others.

At the foot of Johnson Hollow is a large delta formed, apparently in a marginal lake, by the stream flowing down the channel. The top of the delta is at the 1,000 feet contour, with the northern part slightly lower than the southern. The delta is very perfect, with an even slope eastward toward the ice. There is evidence that this delta was built against the ice. Its eastern margin shows several deep kettles and other signs of the melting out of buried ice.

The top of the delta is one hundred feet higher than the Watkins Lake outlet channel, which began only three-fourths of a mile distant. This indicates clearly the deposition of the delta material in a marginal lake rather than in Lake Watkins. There is good evidence that while a large stream was still coming down Johnson Hollow, the ice melted out sufficiently from Seneca valley to cause the draining of this marginal lake and to bring about the initial stage of Lake Watkins at a level one hundred feet lower. At this level, just opposite the beginning of the outlet channel is a second delta built into Lake Watkins by a stream from Johnson Hollow. While forming the lower delta the stream cut a broad channel though the one first formed.

The Johnson Hollow series of channels presents many features of interest. It shows that while an ice-tongue lay in Seneca valley, at least as far as Millport, a lobe pushed westward into the Moreland valley and ended approximately at the head of Johnson Hollow. It also illustrates the case of a stream leaving the ice at one point and returning to it at a lower level several miles distant. This gives a means of estimating the ice slope, which seems to have been about sixty-six feet per mile. There is a possibility, however, though from the evidence it seems very improbable, that, while the upper delta was building in the marginal lake, the ice-lobe from which the stream came pushed for considerable distance into Johnson Hollow; and that it was only during the building of the later delta in the early stage of Lake Watkins that the channels at the head of Johnson Hollow were formed. If this were the case, the ice margin might have had a considerably greater slope, for the ice-tongue would not then necessarily reach as far south as the delta.

SUMMARY

Our study of the Finger Lake channels has brought out some features of interest and importance. It has shown, in the first place, the large number of these channels. It has shown also that, although from their nature the greater number of the channels now visible were formed during the final retreat of the ice, a considerable percentage have an earlier origin. In some of these cases all that can be said concerning the time of their formation is that they antedate the final retreat of the last ice-sheet. In others, notably Cayuta Gorge channel, the development of tributary gorges subsequent to the channel cutting points unquestionably to one or more interglacial intervals at least several times longer than post-glacial time.

Clear evidence of the burial and subsequent melting of large ice masses, with consequent settling of the overlying drift, has been found in one of the channels. Under ordinary conditions it would be difficult to obtain conclusive evidence of settling caused by melting ice because of the difficulty of distinguishing the resulting depressions from normal morainic topography. When, however, such a sinking lowers a portion of the bottom of a large stream channel, the evidence is clear.

One of the most important features of these channels is that they show the direction of the ice flow, and in this are of great value in the mapping of the glacial geology of a region. In favorable cases, especially in connection with *lateral* channels, it is possible to ascertain the slope of the ice with a very fair degree of accuracy.

Glacial channels are easily recognized. They are characteristically flat bottomed and are usually swampy. The banks, in almost all cases, are distinct and, except where disturbed by cultivation, show little effect of post-glacial degradation.